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Is the operational dynamics of artisanal fishing fleet dawdling? A comprehensive study of palk bay, India

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Marine fish resources off Indian shores have been displaying thorough heterogeneity over the years. The catch rates have propelled high during post-independence period and the country experienced tremendous growth in fish production. Technological changes have spurred fish production and exports. Alongside fisheries development, few negative externalities occurred, threatening the long term sustenance of the artisanal sector and the overall fishery resources. Hence, a study was attempted to understand the various sociological, spatial and temporal factors that play a key role in artisanal fishing operations and further to the resultant productivity. Additionally, fishers' compliance towards existing fisheries rules and regulations was also perceived to suggest suitable fisheries management measures. The study was carried out at Ramanathapuram and Pudhukottai districts of Palk Bay. The economic and technical efficiency of the crafts were studied exclusively for traditional and motorized crafts employing costs and returns procedure and Data Envelopment Analysis (DEA) approach respectively. Traditional boats have registered the highest profit margin of 45.61% and least payback period of 0.58 years. Yet, the motorized fishing crafts seem to operate with a mean technical efficiency of 0.85, much higher than that of traditional crafts (0.58).

[Keywords: Efficiency; Fisheries; Management; Resources; Sustenance]

Introduction

Marine fisheries constitute a valuable source of food and employment, and a net contributor to the nation's balance of payment. India is endowed with a lengthy coastline of about 8,129 km, continental shelf of 0.5 million km^2 and an Exclusive Economic Zone (EEZ) of over 2 million km^2 and has been for long a vital occupation for the coastal communities of the country[1]. From the very outset of the Five Year Plans in 1951, modernisation/motorisation of indigenous crafts and introduction of mechanised fishing boats have been accorded towering priority for the development of marine fishery sector. The improved mobility of fishing crafts due to rapid motorisation and augmented exploitation of fish induced many fishermen to shift from traditional to mechanised fishing resulting in immense pressure on the fish stocks and themselves.

Small-scale fisheries play an important role in generating employment, income and livelihood to the fisher folk. It constitutes 81 % of the total fisheries sector in India. But, this sector remains neglected and the fisherfolk are socially and economically backward. Catches of the non-motorized sector has been on the decline since 1970s. Existing intra and inter-fleet competition is the outcome of fisheries overexploitation and Malthusian overfishing[2] in Indian waters. The total number of marine fishing fleet has declined from 2, 38,772 in 2005 to 1,94,490 in 2010, registering a overall decline of 19 %[3]. The number of motorized (6%) and non-mechanised (51 %) craft declined between 2005 and 2010. This showed that there is a strong inclination towards mechanized fishing units by the fisherfolk due to their higher stability, mobility and technical efficiency. There is an alarming need for the reduction in fishing fleet sizes owing to its consequence on collapse of fish stocks[4]. The proliferation of these fishing fleet though increased the catch, had a negative impact leading to growth overfishing, economic overfishing and ecosystem overfishing. Despite the increase in quantity of marine landing, the Catch Per Unit Effort (CPUE) per boat diminished[5]. There is a pressing need to curb existing overcapacity and overexploitation, redistribute remaining effort across the trophic levels[6,7] and adopt responsible fishing techniques and practices. Hence, efficiency studies in marine fishing are significant.

There are various approaches used to measure fishing capacity and overfishing. However, peak to peak method is widely used and it requires the landing and fishing fleet data. When data is limited, the stochastic frontier production function (SFP) and data envelopment analysis (DEA) have been employed in fisheries field to estimate capacity utilization and variable utilization using input and output data of fishing. Unlike SFP, the DEA allows to deal with multiple outputs and specifications of the frontier function. The technical efficiency is influenced by length of fishing craft, engine power, annual fishing days, skipper experiences, electric devices and knowledge of the skipper. Hence, the management of fishery resources could be achieved by restricting venture-fishing fleet which operates under high inefficiency. The inefficient fleets can be eliminated through decommissioning and buy back of vessels[8].

Numerous studies have been conducted to assess the economic performance of fishing crafts of India3,[9-11]. Technical efficiency (TE) studies employing Data Envelopment Analysis (DEA) has multiple advantages over the other production function methods[12-14]. However, data inventory of cost and returns to evaluate the economic performance and technical efficiency of fishing crafts does not exist. Hence, in this study, exhaustive data on the livelihood status, cost and returns and technical efficiency of fishing fleet of Palk Bay, India was collected. The study was duly carried out with hypothesis; there is no economic and technical efficiency variation among different types of fishing fleet in this region. This study would provide valuable inputs to the policy makers, researchers or individuals about the efficiency scores of the operating fishing fleet in the study area.

Materials and Methods

The study was carried out at Ramanathapuram and Pudhukottai districts of Palk Bay, India, being a geographically contained area. The study area also seemed to experience the grave issues of overcapacity of trawlers, over exploitation of the resource and biodiversity loss. Sampling of respondents was carried out using a well-structured, explicit interview schedule in the Palk Bay coast. Considering funds and time limitations, the sample size was fixed as 270. The sample respondents were chosen from eight major fish landing centres of the Palk Bay coast belonging to the traditional (90) and motorised (180) craft types. The survey points include: Nagapattinam, Kodiakarai, Kottaipattinam, Jagadapattinam, Tondi, Mandapam, Pamban and Rameshwaram (Fig. 1). Less

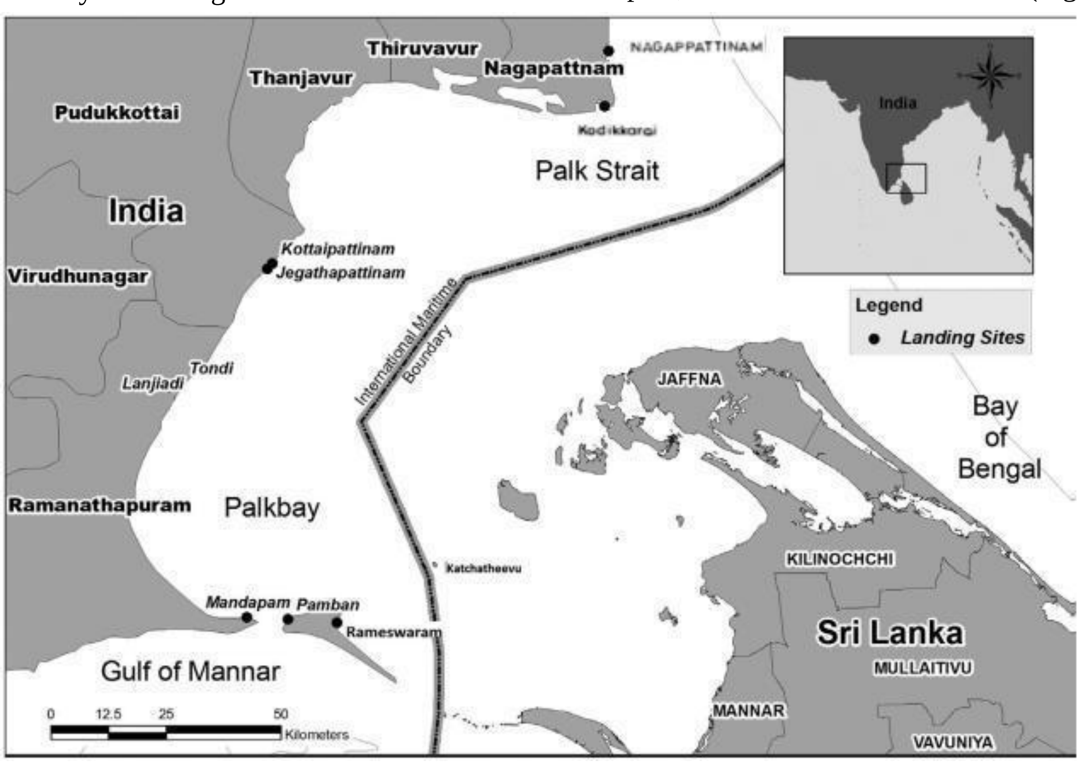

Fig. 1 — Map of Palk Bay Along with the Major Trawl Centres in Tamil Nadu
Source: University of Jaffna, Department of Geography (2012) with slight modifications for the study purpose.

number of sample respondents in the traditional sector was due to the diminishing trend in the usage of traditional non-motorised crafts.The sample frame consists of active fishermen, both owners and labourers. The respondents were selected using simple random sampling procedure. The collection of data from the sample respondents was taken up from February 2014 to November 2014. Pre-tested survey schedules were used to collect primary data.

Cost and earnings and technical efficiency were analysed per fishing trip, with the primary data and the same has been tabulated. Technical efficiency is the ratio of output to input and it reflects the ability of the firm to obtain maximum output from a given set of inputs. In marine fisheries, technical efficiency reflects the efficiency of crafts and gear. DEA method was first developed by Charnes under the assumption of constant returns to scale (CRS)[15]. The same model was redeveloped considering variable returns to scale (VRS)[16]. In the present study, DEA method developed by Coelli was employed to construct the non-parametric production frontiers for different independent study variables to elucidate the efficiencies of different crafts across the study area[12]. In the study, efficiency has been calculated under the assumption of CRS that gives the '*overall technical efficiency'* score.

Coelli specified that the measure of technical efficiency under CRS[17] is as follows,

$\text{Max } \theta, \lambda\ \theta,$

subject to $-\theta y_i + Y\lambda \geq 0$

$x_i - X\lambda \geq 0$

$\lambda \geq 0$

where θ is the i^{th} craft TE as compared to the other DMU, y_i is the output quantity of the i^{th} DMU, X_i is the input quantity of the i^{th} DMU, Y is the output data for N DMU, λ is Nx1 vector of constants, x is the input data for N DMU and N is the number of DMU. $Y\lambda$ and $X\lambda$ are the efficient estimations on the frontier. It was measured by using the DEAP (version 2.1), which was developed by Coelli[12]. The TE was measured as an independent variable of annual fish catch.

The average fish catch of the sample fishermen was taken as the output variable in DEA model and expressed in kilogram. Separate models were run for each type of fishing namely, traditional and motorised. The input variables were measured as diesel in litres, ice in bars, water in litres, oil in litres, food in rupees, crew wages in rupees, boat OAL in metres, gear mesh size in millimetre, engine power in HP, distance to the fishing ground in nautical miles, age, experience and education in years[18,19].

Results and Discussion

The fishing units operating along the Palk Bay have adopted different strategies of operations depending on a few key factors. The strategies show notable variations (both spatially and temporally) even within the artisanal sector. Hence, these key factors have been studied comprehensively.

Key factors in fishing – Ramanathapuram and Pudhukottai district

The key factors influencing the fishing operations have been demarcated within the artisanal fishing sector and are worth examining (Table 1).

Distance to the fishing ground

The distance to the fishing ground is a crucial factor affecting the economics of operations of a vessel and varies with the type of crafts and resources exploited. In the study area, the traditional fishing vessels were generally operated within 3 Nm from the shore, unlike the motorised crafts who venture about 35Nm from the shore.

Crew strength

The type of fishing craft and operation decides the manpower of a vessel. The crew strength is a key factor of production. Except trawlers, all other types of fishing units depend on human power for the operation of gears. It can be pursued from Table 1 that the average crew strength ranged from two in traditional units to four in the motorised sector.

Duration of fishing trips

The number of days per fishing trip has a bearing over the average number of fishing days per year. The traditional and motorised units usually have daily fishing operations as against the trawlers who stay on fishing for multiple numbers of days. In contrast, all the fishing sectors of Ramanathapuram and Pudhukottai districts of Palk Bay, were all the more

Table 1 — Summary of fishing operations across the artisanal fishing sector–Palk Bay

Average of factors	Traditional	Motorised
Distance to fishing ground (Nm)	3	35
Crew strength	2	4
Number of days per fishing trip	1	1
Number of hauls per fishing trip	3	6
Number of fishing trips in a month	24	16
Annual fishing days	288	192

Source: Field data

restricted to single day fishing operations with very few exceptions. This was due to the existence of three day four day rule imposing temporal restriction on all fishing units. By this rule, the motorised and mechanised units get to fish four and three days in a week, respectively. The number of trips in a month was maximum for traditional (24), as against the motorised sector with 16 trips. The above rule has no bearing on the traditional fishing units and they fish daily. This was the reason for higher number of fishing trips in this sector. Similarly, the annual days of operation vary drastically between the fishing sectors. While in traditional sector, average annual days of operation amounted to 288 days, in motorised sector it was 192 days. A similar studyworked out theaverage annual fishing days of fishermen in the non-mechanised sector of Pudhukottai district to be 243, 138 and 136 for canoe, vallam and FRP boat categories, respectively[20].

Technical specifications of crafts and gear

With the emergence of Tamil Nadu Marine Fisheries Regulation Act (TNMFRA) in 1983, several rules have been enforced to cope with the need to protect the interests of small scale fishers and to subsequently regulate marine fisheries[21]. Technical specifications discussed here include: craft length (OAL), breadth, engine horse power (HP), gear mesh size, fish hold, fuel hold and water hold capacity. These specifications play a key role in determining the efficiency and catch of the vessel employed and vary immensely between the different fishing sectors. The OAL of the traditional craft range was found to be 3 – 4 m, followed by 7 – 10 m in motorised sector. Similarly, the engine horse power ranged between 9 – 90 HP in the motorised sector (Table 2). Although the TNMFRA Act includes regulations on mesh size of trawl-nets and other gears, the actual implementation of this management tool is far from enforcement in the study area. However, manpower in the Fisheries Department is stated to be not sufficient enough to stringently enforce the regulations. The other parameters like fish hold, fuel hold and water hold capacity of the fishing vessel were concurrent to the efficiency and catch of the same.

Table 2 — Technical specifications and capacities of crafts and gears across the artisanal fishing sector–Palk Bay

Range values of Particulars	Traditional	Motorised
Craft OAL (m)	3 – 4	7 – 10
Craft breadth (m)	1.1 – 1.2	1.4 – 3.0
Fish hold capacity of craft (kg)	40 – 50	200 – 1000
Fuel hold capacity of craft (litres)	--	15 – 50
Water hold capacity of craft (litres)	--	20 – 50
Engine Horse Power (HP)	--	9 – 90
Gear mesh size (mm)	25 – 127	45 – 130

Economic analysis of marine fishing activity

There has been a conspicuous reduction in catch per unit effort (CPUE) despite the increased landings. Overcapacity and overcapitalization had endorsed to this prevalent issue resulting in tough competition among the craft operators making this profession a capital intensive and precarious one. Despite these constraints, the sector still sustains largely because of the dramatic rise in the price of most of the fishes. In this context, study on economic viability and financial feasibility of crafts stands imperative complementing to the research objectives.

The Cost, Revenue and Profitability of the artisanal crafts had been estimated to study the economic viability and financial feasibility of crafts. The total cost per trip was calculated from the fixed cost and variable cost. Fixed cost includes depreciation of craft, gear and engine, interest on capital and repairs and maintenance. Depreciation was calculated on the basis of the expected life of the fishing craft, gear and engine through straight line method. While the depreciation of crafts and engine was obtained to be 20 %, depreciation of gear was 33 %. Apart from this, interest on capital was fixed at 18 % based on the average interest rates of the sample respondents. Variable costs include expenses on diesel, ice, oil, drinking water, food and crew wages. Variable or operating costs vary with the level of inputs depending on the type and operation of craft. Fuel occupies the major share of operating cost in all sectors. The value of diesel was computed using current diesel rate (Rs. 53/litre as on March' 2015). The diesel subsidy amounts to Rs. 9.83 per litre under current scenario. To avoid double entry, the value of subsidized diesel was calculated (@ 3600 litres/year for motorised vessels) per fishing trip and the same was deducted from the operating cost to arrive at the total operating cost. Gross returns were calculated from the quantity of fish and the respective landing centre price of the fish. Total cost was deducted from the gross returns to arrive at net profit per fishing trip.

Analysis of economics of different types of fishing units showed that most of the fishing units, on an average, run on profit. The comparative economic efficiency of traditional and motorized vessels is given in Table 4. On comparing the different types of fishing units, the initial investment of traditional units was the lowest (Rs. 28,188.89). The average initial investment worked out at Rs. 6,62,266.66 for a single day motorised unit undertaking 192 fishing trips in a year. The variable cost accounted for about 64 % of the total cost in motorized crafts. Major share of the variable cost was attributed by fuel and wages. Narayanakumar mentioned that the fuel cost and labour cost accounted for 54 % and 25 % of the total variable cost of motorized and mechanisedvessels[3]. The high share of fuel cost in mechanised craft is due to the longer distance travelled and the intense use of mechanical power for both propulsion and fishing as most of the mechanised vessels use the active gear - trawl net.It can be pursued from Table 3 that, total fixed cost of traditional boats worked out to Rs. 201.69 per fishing trip and that of motorised vessels worked out to Rs. 3,258.25 per fishing trip. Likewise, total operating cost of motorised boats amounted out to Rs. 5,815.81 per fishing trip. The gross revenue realized per fishing trip for the traditional boats amounted to Rs. 370.83 against the total cost of Rs. 201.69. A motorised vessel, on an average, incurred Rs. 9,074.06 as total cost and earned about Rs. 11,658.06 as gross revenue. A similar study calculated the mean gross income per fishing trip of fishermen in the non-mechanised sector of Pudhukottai district. It was found to be Rs. 1843.42, Rs. 2444.77 and Rs. 2116.97 for canoe, vallam and FRP boat categories, respectively[20].

The net operating profit per trip of motorised (Rs. 5,842.25) was much higher than traditional (Rs. 370.83) vessels. Also, the net profit per trip of motorized vessel (Rs. 2,584.00) was much higher than traditional (Rs. 169.14) vessels. Similar results were observed on comparing the economic efficiency of motorised and mechanised fishing units, with mechanised vessels earning higher net profit (Rs. 83,991) than the motorised (Rs. 4,434)[10]. The profit margin of motorised vessels was found to be 22.16 %. Of the two sectors, traditional boats have registered the highest profit margin of 45.61 % and least payback period of 0.58 years.

Table 3 — Costs and returns per trip of sample fishing units (in Rupees) – Palk Bay

Particulars	Traditional	Motorised
1. Initial Investment		
a. Craft and Engine	16188.89	619833.33
b. Gear and Accessories	12000.00	42433.33
Total	28188.89	662266.66
2. Fixed cost		
a. Depreciation		
(i) Craft & Engine (20%)	13.49	516.53
(ii) Gear (33%)	16.50	58.35
b. Interest on Investment	21.14	496.70
c. Repairs & maintenance	150.56	2186.67
Total	201.69	3258.25
3. Operaring cost		
a. Fuel	0	1069.42
b. Ice	0	55.00
c. Water	0	300.00
d. Oil	0	125.00
e. Food	0	490.00
f. Crew wages	0	3963.89
Total	0	6003.31
4. Value of subsided diesel realised	0	187.50
5. Total operating cost (3 – 4)	0	5815.81
6. Total Costs (2+5)	201.69	9074.06
7. Gross Revenue	370.83	11658.06
8. Net Operating Income (7 - 5)	370.83	5842.25
9. Net Profit (7 - 6)	169.14	2584.00
10. Profit margin % [(9/7)*100]	45.61	22.16
11. Annual days of operation	288	192
12. Payback period	0.58	1.33

Technical efficiency of fishermen

An analysis of the technical efficiency of different boats of Palk Bay was carried out in order to assess their fishing efficiency and capacity. The output in terms of fish catch (Kg) was considered as the dependent variable. The fishing inputs which decide the fish catch were considered as the independent variable. The major inputs include diesel, ice, water, oil, ration, crew wages, crew number, boat OAL, gear mesh size, engine HP, distance to the fishing ground, annual number of fishing trips, age, education and experience of the fishermen.

Technical efficiency of fishermen operating traditional craft

The Table 4 shows the number of traditional fishers who are coming under different types of return to scale. Only about 4 (4.44 %) fishermen had an overall

Table 4 — Technical efficiency of fishermen operating artisanal crafts

Particulars	Traditional	Motorised
Efficiency		
< 0.5	35 (38.89)	0 (0)
0.5 – 0.9	51(56.67)	100 (55.56)
> 0.9	4 (4.44)	80 (44.44)
Mean	0.58	0.85
Standard deviation	0.14	0.14
Minimum	0.34	0.51
Maximum	1	1

Source: Field data

technical efficiency under CRS assumption. The remaining 86 (96.56 %) fishermen had technical efficiency values ranging from 0.50 to 0.90 indicating that they were technically inefficient with respect to input allocation (Table 4). The overall technical efficiency ranged from 0.34 to 1.00 with a mean level of 0.58. It is inferred that 96.56 % of the fishermen who were technically inefficient could cut down their input use level by 0.42 % and yet achieve the level of output obtained by 4.44 % of the efficient fishermen. Similar to the TE of traditional crafts, Esmaeili reported that the Iranian fishery at the Persian Gulf witnessed efficiency of 0.6 for the small crafts[5].

Technical efficiency of fishermen operating motorised craft

In the case of fishermen operating motorised fishing craft, 80 (44.44 %) fishermen had an overall technical efficiency under constant returns to scale assumption (CRS). The remaining 100 (55.56 %) fishermen had technical efficiency values ranging from 0.50 to 0.90 indicating that they were technically inefficient with respect to input allocation (Table 4). The overall technical efficiency ranged from 0.51 to 1.00 with a mean level of 0.85. It is inferred that 55.56 % of the fishermen who were technically inefficient could cut down their input use level by 0.15 % to achieve the level of output obtained by 44.44 % of the efficient fishermen.Walden and Tomberlin also studied the fishing capacity and efficiency of crafts in Sweden and found that larger size crafts had better efficiency than the smaller one[22]. Similar to their finding, the motorized crafts which were larger than the traditional crafts, were found to be comparatively efficient than the latter.

Conclusion

The present study portrays an explicit picture of the different attributes of fishing in the Ramanathapuram and Pudhukottai districts of Palk Bay. The motorized fishing crafts seem to operate with a mean technical efficiency of 0.85, much higher than that of traditional crafts (0.58). These empirical results revealed that the motorised crafts were much profitable and efficient compared to the traditional crafts. Despite the better profit margin (45.61 %) of traditional crafts, 38.89 % of them seem to operate below 0.5 level of technical efficiency. Hence, it is recommended that those vessels operating under moderate efficiency incessantly over the years, be removed from the industry so as to facilitate the motorised crafts to harvest better resource rents, in place of inefficient traditional crafts.This study has been undertaken only in Palk Bay representing only a portion of the State. The information obtained cannot be subjected to over generalization towards other zones of the State. Hence, more comprehensive studies covering the other zones of the State, needs to be encouraged, to provide a holistic picture of the prevailing scenario. These efficiency studies would benefit policy makers or researchers with indispensable input on sustainable fishing capacity.

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